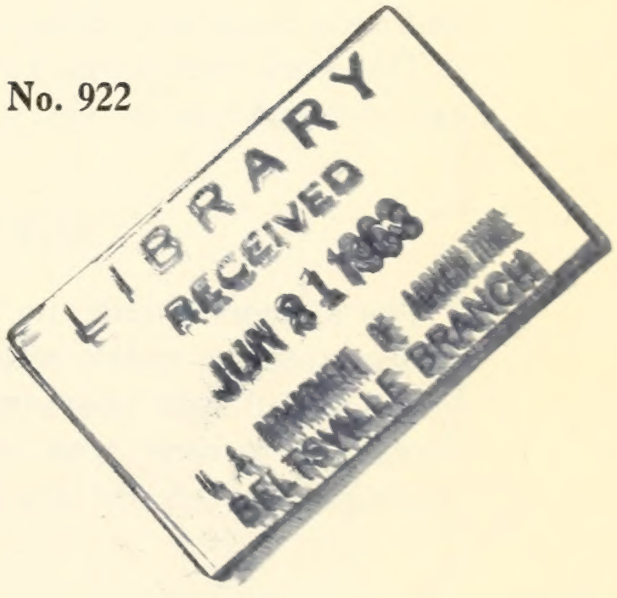
PELLET SEEDING on WESTERN RANGELANDS

Miscellaneous Publication No. 922



Agricultural Research Service and Forest Service
UNITED STATES DEPARTMENT OF AGRICULTURE
in cooperation with
Bureau of Indian Affairs and Bureau of Land Management
UNITED STATES DEPARTMENT OF THE INTERIOR

PREFACE

The value of seeding western rangelands with pelleted seed has been widely discussed. Some people have claimed that this method would revolutionize range seeding and bring untold benefits to the western range and the livestock industry. Others have claimed that it is a waste of seed and money.

Because of these divergent views on the value of pelleted seed for range use, the U.S. Department of Agriculture and the U.S. Department of the Interior present here a review of information on seeding pelleted seed on rangelands. This review covers reports of laboratory and greenhouse tests on seeds pelleted by the various processes, as well as experimental field tests and large-scale seedings where pelleted seeds were used. Information is given on the locations, the procedures followed, the results obtained, and the effectiveness of using pelleted seed as a range-improvement practice.

The work summarized represents the efforts of Federal and State agencies and commercial interests.

ACKNOWLEDGMENTS

The authors thank the agencies and the individuals who supplied information on pellet studies and on experimental and large-scale seedings and who provided materials for testing. The authors also thank all persons who initiated and carried out the studies and seedings reported and who reviewed the manuscript before publication.

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Washington, D.C. Issued May 1963

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.—Price 20 cents

PELLET SEEDING on WESTERN RANGELANDS

By A. C. Hull, Jr., Ralph C. Holmgren, W. H. Berry, and Joe A. Wagner [1]

Seed pellets for range seeding are designed to be broadcast by airplane, usually on unprepared seedbeds. They are made by enclosing seed in soil or other material, and have been used for seeding more than 180,000 acres on western rangelands. Three types of seed pellets have been used for range seeding: compressed, coated, and extruded. Compressed earthen pellets, generally spherical, are made by running a seed-and-soil mixture through four pressure disks to form a hard, round, earthen pellet. Coated seed pellets are made by coating individual seeds with successive layers of clay or other finely powdered material. Extruded seed pellets are made by pressing a seed-and-soil mixture through round openings to form cylindrical pellets.

Standard seeding recommendations for obtaining successful stands of grass species have been developed through years of research. These recommendations are (1) that the competing vegetation be killed and (2) that the seed be covered (Hull and Stewart, 1948; Stewart, 1949; Plummer *et al.*, 1955).[2]

Conventional seeding methods are slow, and many years will be required to seed the large area of western rangelands where seeding is needed. Therefore, there has been a constant search for quick and low-cost seeding methods.

Broadcasting seed by airplane was an early, and has been a constant, effort for rapid range seeding (Teutsch, 1928; Stanton,

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[2] Names followed by year of publication refer to References, p. 32.

1929; Hull and Stewart, 1948). Reports on airplane seeding stated that broadcasting pelleted or nonpelleted seed is successful only where competing vegetation is eliminated and where natural seed covering is provided, as by leaf-fall of deciduous trees or deep ashes of timber burns (Plummer and Stewart, 1944; Bleak and Phillips, 1950; Plummer *et al.*, 1955).

Concurrently with early airplane seeding of rangelands, the pelleting of seed was developed commercially. Pelleting combines seeds into larger bodies. When seeds are very small, pelleting makes them easier to handle and facilitates uniform distribution with conventional planting equipment. Airplane broadcasting of pelleted seed seemed to offer promise. It was felt that the airplane would provide speed, that pelleting would provide even distribution, and that either the pelleting material or ground penetration of the seed pellets would provide seed covering (Ashley, 1945; Haystead, 1945).

As the first large-scale airplane seedings of rangeland with compressed earthen pellets were carried out, the following advantages were claimed for pellets:

(1) Seeding by airplane could be done at half the cost of conventional seeding methods and at several times the speed (Haystead, 1945; Kimball, 1949).

(2) Because of their weight, pellets could be seeded in the wind; in straight rows; or, by using a bombsight, even in curving rows on the contour (Ashley, 1945).

(3) Pellets could be supplied with growth-promoting vitamins and fertilizer to stimulate rapid seedling growth (Haystead, 1945; Kimball, 1949).

(4) Seed in pellets could be made safe from disease, insects, rodents, and birds by adding fumigants and repellants (Ashley, 1945; Haystead, 1945; McSurely, 1945).

(5) Either pellets had enough moisture to start germination or seeds in pellets required less moisture for germination than regular seed (Ashley, 1945; Kimball, 1949).

(6) Pointed but perforated metal pellets could be used for penetrating the litter of forest floors and for other special conditions (Ashley, 1945; Haystead, 1945; Kimball, 1949).

(7) On dry areas, special explosive pellets could blast out pits to hold moisture for normal pellet seeding (Ashley, 1945).

The earliest range seedings with compressed earthen pellets were made during the years 1946–49. In 1949 and 1954, large-scale range seedings were made with coated seed pellets. In 1961, seedings were again made with compressed earthen pellets. In all, 180,057 acres were seeded with pelleted seed in six Western States; about 95 percent was seeded with compressed earthen pellets.

SEED PELLETS

The manufacture and characteristics of the three types of seed pellets for seeding rangelands follow.

Compressed Earthen Pellets

Manufacture and composition

Compressed earthen pellets are manufactured by a machine consisting of four gearlike wheels with a series of quarter-spherical depressions around the rim. The four wheels meet at a common point and mesh so that the seed-and-soil mixture fed into the machine is pressed from four sides to form a spherical pellet. The wheels exert considerable pressure in forming the pellets. Seemingly dry soil is made into extremely hard pellets. The normal density of uncompressed clay soil in Idaho is about 100 pounds per cubic foot. Compressed pellets have densities one-third to three-fifths greater than normal (Tisdale and Platt, 1951).

Pellets are made with soil on or near the seeding site. Clay loam of low moisture content is preferred. Soil that contains quartz particles or other abrasive material causes rapid wear on the machines. This results in poor pellets; they become larger with machine wear and in extreme cases come out of the machine as connected "strings." Tisdale and Platt (1951) observed at one stage of a pelleting operation that "half or more of the processed material passed through the equipment either totally unpelletized or so loosely incorporated that it disintegrated in screening or other handling." When the soil is too moist or has a high percentage of coarse particles, pellets are not firm and they fragment readily in handling (Wagner, 1949).

Description

The size of the compressed pellet depends on the size of the seed and ranges from ¼-inch diameter for small seeds to ⅜-inch or more for larger seeds (fig. 1). The number of pellets ranges from 1,450 to 1,880 per pound for the ¼-inch size and from 420 to 630 for the ⅜-inch size (Wagner, 1949; Bleak and Phillips, 1950). Some characteristics of pellets used in the 1948 Manti-LaSal seeding are given in table 1.

Seeds per pellet average from 5 to 10, but imperfect mixing causes variations in the number in each pellet. Examination of pellets from many projects has shown a range of from none to 59 seeds per pellet and averages for different species of from 3.6 to 28 seeds per pellet. For crested wheatgrass from several projects, the average number of seeds per ⅜-inch pellet ranged from 7.5 to 20 (Allen, 1948; Stevenson, 1949; Bleak and Phillips, 1950; Tisdale and Platt,

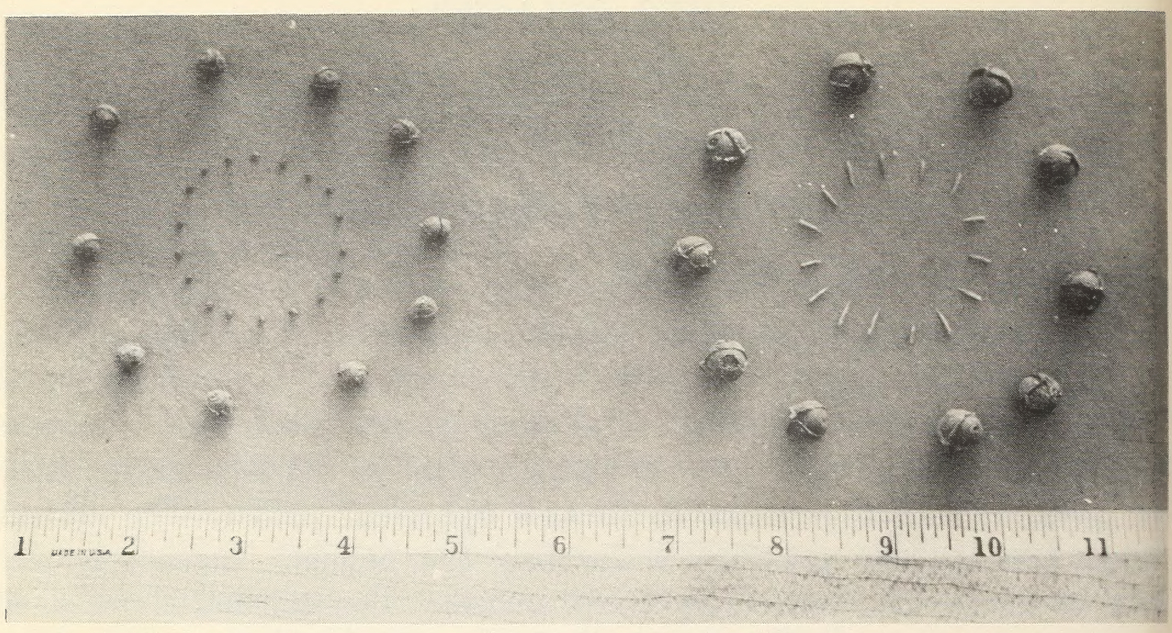

Figure 1.—*Left,* Yellow sweetclover, 1/4-inch compressed earthen pellets and nonpelleted seed; *Right,* crested wheatgrass, 5/16-inch compressed earthen pellets and nonpelleted seed.

TABLE 1.—*Characteristics of seed and compressed seed pellets used in seeding the Manti-LaSal project in Utah, 1948*

Species	Diameter of pellet	Ratio: seed weight to pellet weight	Average seeds per pellet	Germination	
				Before pelleting	After pelleting
	Inches		*Number*	*Percent*	*Percent*
Bulbous bluegrass	1/4	1:31	10.2	98	11
Timothy	1/4	1:33	25.4	92	18
Yellow sweetclover	1/4	1:39	4.6	92	78
Crested wheatgrass	5/16	1:30	8.7	95	39
Orchardgrass	5/16	1:54	18.2	86	33
Smooth brome	3/8	1:74	4.3	62	28
Tall oatgrass	3/8	1:97	3.6	89	41

Source: Tables 5 and 6, Bleak and Phillips (1950).

1951). With 5 seeds per pellet, as recommended for crested wheatgrass, and 1 pellet per square foot, there would be 217,800 seeds or 1.2 pounds of seed per acre.

The ratio of seed to soil weight varies with the seed and pellet size. The range for grass seed is from 1:20 to 1:920 (Rudolf, 1949; Bleak and Phillips, 1950; Tisdale and Platt, 1951). Thus, from 20 to 920 pounds of soil must be handled and transported with every pound of seed. The average for 3/8-inch crested wheatgrass pellets is 1:60. At a seeding rate of 1 pellet per square foot and 1.2 pounds of seed per acre, this is 72 pounds of soil per acre. Even at low seeding rates, the weight to be carried by airplane is considerable.

Effects of pelleting

Seed damage as the result of heavy compression during processing is probably both mechanical and physiological. Tisdale and Platt (1951) found an average of 38 percent of broken seeds in crested wheatgrass pellets from five projects in Utah, Idaho, Nevada, and Wyoming. Stevenson (1949) reported many broken seeds in crested wheatgrass pellets made at Thorn Creek, Idaho. Bleak and Phillips (1950) observed that pelleting damaged and broke about 25 percent of the seeds of smooth brome and tall oatgrass on the Manti-LaSal project.

Viability of apparently unbroken seed of most species is reduced in pelleting by compression. Only small, hard, rounded seeds of a few species maintain a reasonable percentage of viability. Germination percentages of pelleted and nonpelleted seed on the Manti-LaSal project are shown in table 1. Data from several sources on percentage of germination of pelleted and nonpelleted seed are as follows:

	Germination			
Species	*Pelleted (percent)*	*Nonpelleted (percent)*	*Location*	*Authority*
Crested wheatgrass	9	68	Idaho	Tisdale & Platt (1951)
Do	12	84	Utah	Do.
Do	10	86	Arizona	Allen (1948).
Do	25	73	Idaho	Stevenson (1949).
Yellow sweetclover	38	78	do	Tisdale & Platt (1951).

Allen (1948) found that 38 percent of the pellets containing crested wheatgrass seed from the early Arizona seedings failed to produce any seedlings. Similar results were obtained at the Federal-State Seed Laboratory in Sacramento, Calif.[3]

The slower rate of germination or death of sound seeds following pelleting by compression is presumed to result from secondary effects of pressure or a curtailed oxygen supply (Silen, 1948; Bleak and Phillips, 1950; Tisdale and Platt, 1951). Moomaw *et al.* (1954) determined by the vital-stain technique that the nongerminating, but sound-appearing, seeds were dead rather than merely dormant.

Pellet behavior

One advantage of compressed earthen pellets is that they weigh enough for good aerial distribution, even in moderate winds. The claim that these pellets had enough weight to cause them to penetrate range soils (Ashley, 1945) was not realized. On pellet seedings in Idaho there was seldom any penetration of soft or even wet soil, let alone normal range soils (Tisdale and Platt, 1951). In Arizona, even on moist areas around ponds and lakes, the pellets usually hit, left

[3] Unpublished data from the U.S. Bureau of Indian Affairs.

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indentations, and rolled or bounced along the surface. On fresh gopher mounds or on loose, recently plowed soil, the pellets bounced or rolled except when they hit the surface at an angle of about 90°. Even then they did not bury themselves and could still be seen partially embedded in the loose soil (Wagner, 1949).

It has also been claimed that the soil in compressed earthen pellets would provide covering for the seeds. Observations in Idaho revealed that as pellets were moistened by rains, the soil covering softened and spread out into a rounded mound, and the seeds were usually left with little or no covering. The disintegrated pellet mound was exposed and more susceptible to rapid drying than the surrounding soil surface.[4]

Coated Seed Pellets

Coated seed pellets were developed to aid in attaining even distribution of small vegetable and flower seeds. These pellets are designed to be sown at the same depths recommended for nonpelleted seed. Coated pellets of sugar beet seeds were first made commercially during World War II. In 1949 and 1954 coated seed pellets of crested wheatgrass and intermediate wheatgrass were used for seeding large range areas in Idaho by airplane.

Manufacture and composition

Coated seed pellets are made by building up a coating of numerous layers around the seeds as they are tumbled in a slowly revolving drum. There are two common types. One has a coating of clay; the other is coated with finely powdered feldspar and other materials bonded with a plastic adhesive. The seeds are shipped to a central plant for coating. Small amounts of fertilizers, growth stimulants, growth hormones, fungicides, insecticides, and rodent repellants are often added and the alkalinity of the coating can be controlled (Westrin, 1948; Rudolf, 1949; Gatherum, 1951; Carolus, 1954; Nissley, 1955; Hull, 1959).

Description

Coated seed pellets are the same general shape as the seed itself, but somewhat larger (figs. 2 and 3). A seed or some other piece of plant material forms the nucleus of each pellet. Seed lots of high purity normally have one seed per pellet. Trashy seed has less. Pellets of crested wheatgrass often contain more than one seed. Tisdale and Platt (1951) found an average of 1.3 seeds of crested wheatgrass per

[4] Unpublished data from the Intermountain Forest and Range Experiment Station, Ogden, Utah.

Figure 2.—Crested wheatgrass seed: Top to bottom, nonpelleted seed, coated seed pellets, and compressed seed pellets.

pellet. In the 1954 Idaho seeding there was 0.98 seed of crested wheatgrass and 0.92 seed of intermediate wheatgrass per pellet.[5]

When crested wheatgrass seed is pelleted, 1 pound of seed goes into each 3 to 8 pounds of pellets. The ratio with intermediate wheatgrass is about 1 to 4 (Tisdale and Platt, 1951; Hull, 1959).

[5] Unpublished data from Agricultural Research Service, Logan, Utah.

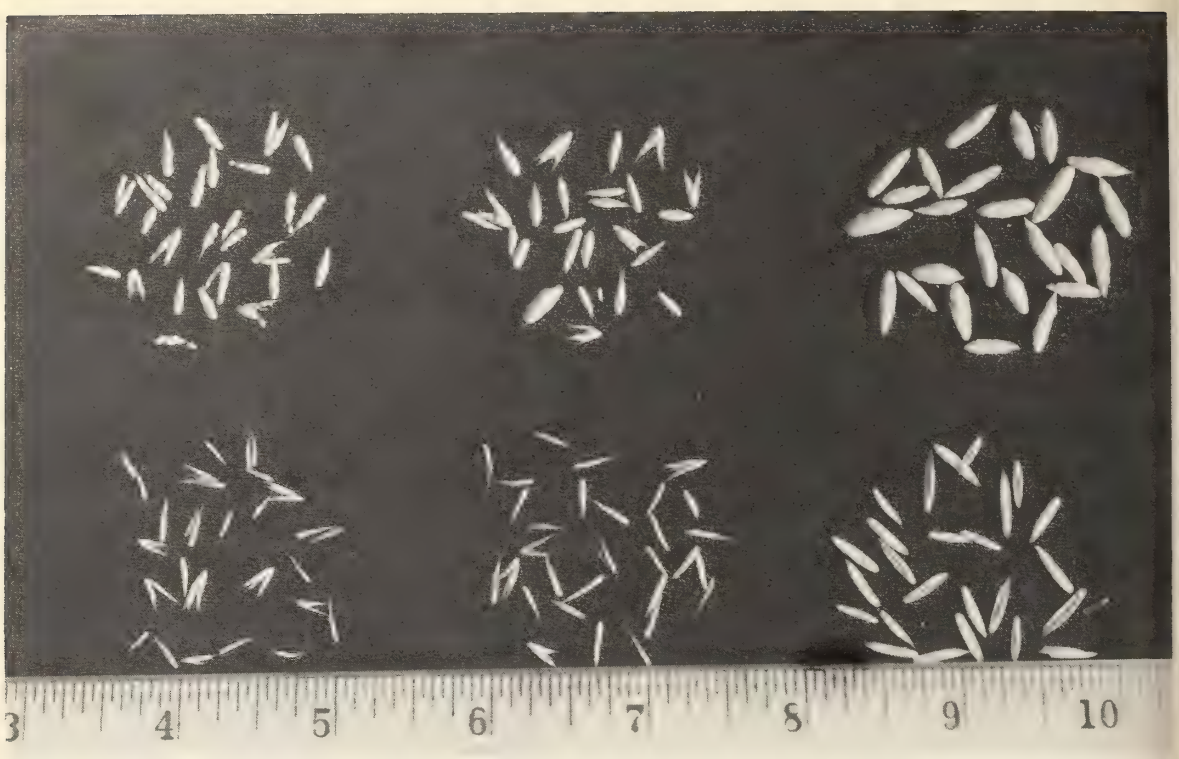

Figure 3.—Pelleted (upper) and nonpelleted (lower) seeds of crested wheatgrass (left and center) and intermediate wheatgrass (right). The pellets at left are coated with clay; those at center and right have a plastic-feldspar coating.

Effects of pelleting

Seed damage by the coating process is low. Tisdale and Platt (1951) found only 8 percent of broken seeds in coated pellets of crested wheatgrass.

Germination of coated seeds is similar to that of nonpelleted seeds. Tisdale and Platt (1951) found a germination of 77 percent in the laboratory and 83 percent in the greenhouse as compared to 85 percent for nonpelleted seed. Gatherum (1951) listed 49 types of seed coatings. Emergence as compared to nonpelleted seed was as follows: 10, lower; 1, higher; 38, not significantly different. Hull (1959) compared the percentage of germination of two types of coated crested wheatgrass seed and one type of coated intermediate wheatgrass seed with nonpelleted seed from the same lots in a germinator and in a greenhouse. Pelleting had no significant effect on germination. Moomaw *et al.* (1954) found little difference in germination between coated seed pellets and nonpelleted seed of five species of range grasses.

Pellet behavior

Although coated pellets are less affected by wind than nonpelleted seed, they are inferior to compressed pellets for airplane distribution. The coated pellets fall slowly; and when they strike the earth, they

bounce and do not penetrate the soil, even on loose, freshly plowed soil (Hull, 1959).

Coated pellets absorb water readily. The clay pellet coating disintegrates immediately on wetting, but the plastic-feldspar coating remains intact. After 50 drops of water were dropped on feldspar pellets there was no sign of breakdown (Hull, 1959). Alternate wetting and drying in the field cause the plastic-feldspar pellets to swell and split open on the upper surface and then gradually disintegrate. During this period the encased seeds are held off the ground surface by the layer of pelleting material. The seeds in coated seed pellets, like those in compressed earthen pellets, are more susceptible to drying than nonpelleted seeds lying on the ground surface.[6]

Extruded Seed Pellets

Extruded seed pellets have been studied only in the laboratory and in one greenhouse test, hence are but briefly mentioned.

Manufacture and composition

In the manufacture of extruded pellets a hard paste-like seed-and-soil mixture is forced under great pressure through round openings. The brittle extruded cylinders are broken up to form short cylindrical pellets.

Effects of pelleting

Tisdale and Platt (1951) reported an average of 7.6 seeds of crested wheatgrass per extruded pellet, of which 41 percent were broken. Germination of seed in extruded pellets was 10.5 percent in the laboratory and emergence was 11 percent in the greenhouse.

General Characteristics of Pellets

Pellets do not bury themselves in normal range soil nor does the pelleting material provide seed covering (Wagner, 1949; Hull, 1959). Except for the rare occasions when natural covering is provided by loose soil, deep ashes, or leaf fall, pelleted seeds that germinate do so on the soil surface. As often happens when nonpelleted seed is sown broadcast, seedlings from pellets are poorly rooted, and the part of the plant that should develop into a root crown is above ground.

Troughton (1957) cites the work of several investigators who have shown that development of a nodal root system is necessary for establishment and survival of perennial grass plants. This nodal

[6] Unpublished data from the Intermountain Forest and Range Experiment Station, Ogden, Utah.

root system grows from the shoot, the part of a seedling that is above the seed.

On a compressed pellet seeding in southern Idaho, Moomaw *et al.* (1954) observed about 25 percent of the first-year seedlings to be "lying loosely on the soil surface and attached by only two or three roots." Though these plants had many tillers, they had as much as 6 inches of root exposed. Only 5 percent of the loosely attached seedlings survived into the second growing season as compared with 50-percent survival for normally rooted seedlings.

In another test in Idaho compressed earthen pellets, coated seed pellets, and nonpelleted seed were broadcast on small plots on a clean sagebrush burn. On all plots 30 to 35 percent of the seedlings that lived into their first summer had about one-fourth inch of their single primary roots exposed. They lay on their sides and rolled about in the wind. Of the original poor stands, only 4 to 8 percent were alive at the end of the growing season.[7] In both of these tests, germination of seeds on the soil surface resulted in plants with little chance of developing good root systems.

The materials used in pelleting have sometimes included various kinds and amounts of fertilizers, fungicides, insecticides, rodent repellants, growth hormones, and other additives to stimulate seed germination and seedling growth (Silen, 1948; Rudolf, 1949; Gatherum, 1951; Moomaw *et al.*, 1954). Gatherum (1951) and others found no increase in germination or seedling vigor as the result of various additives. One rodent repellant, dry lime-sulfur, did not deter rodents from breaking open compressed earthen pellets and consuming the seeds (Wagner, 1949).

SEEDINGS WITH COMPRESSED EARTHEN PELLETS

Large-scale seedings with compressed earthen pellets and with nonpelleted seed were made in Arizona, New Mexico, Idaho, Wyoming, Nevada, and Utah, from 1946 to 1961 (table 2). Experimental field seedings were made with different methods of seedbed preparation on many types of vegetation. Most of the experimental seedings were in connection with large-scale seedings and are discussed with them.

Papago Indian Reservation, Arizona

The first large-scale airplane seeding of rangeland with compressed earthen pellets was made at the San Vincente Ranch, on the Papago Indian Reservation in Arizona. It was on desert-shrub type of vegetation at an elevation of 2,800 to 3,400 feet.

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[7] Unpublished data from the Intermountain Forest and Range Experiment Station, Ogden, Utah.

Procedures

Pellets were broadcast by airplane on 10,120 acres of unprepared seedbed between April 25 and June 24, 1946. Lehmann lovegrass and sand dropseed were used at a ratio of 2:1. The seeding rate was one pellet per square foot with six to eight seeds per pellet.

Results

Good summer rains fell 10 days after seeding, and seedlings became established in the native vegetation. Rains continued and though moisture was slightly below normal, there was good growth of all plants. In November 1947, there were only 75 plants of Lehmann lovegrass per acre or 1 plant per 581 square feet. The seeding was considered a failure (Wagner, 1949; Wagner and Kinkor, 1950). In 1954 there were 83 plants per acre and in 1961 there were a few plants left.

TABLE 2.—*Description of large-scale and experimental pellet seedings on western rangelands, 1946–61*

COMPRESSED EARTHEN PELLETS

Location and year seeded	Area seeded to pellets by airplane	Comparative experimental seedings to pellets and seedings to nonpelleted seed
	Acres	
Papago Indian Reservation, Arizona, 1946.	10, 120	
San Carlos Indian Reservation, Arizona, 1946.	20, 000	28 acres disked and drilled to pellets (2 plots); 4 acres drilled to nonpelleted seed (3 plots).
Hopi Indian Reservation, Arizona, 1946–47.	20, 000	
Navajo Indian Reservation, Arizona and New Mexico, 1947–48.	39, 708	810 acres airplane broadcast to nonpelleted seed.
Thorn Creek, Idaho, 1947–48.	[1] 20, 952	Many sample plots established.
Muskrat Creek, Wyoming, 1947–48.	21, 000	
Golliher Mountain, Nevada, 1948.	15, 360	Small area burned and drilled to nonpelleted seed.
Manti-LaSal National Forest, Utah, 1948.	6, 443	1,284 acres airplane broadcast to nonpelleted seed. 73 acres divided into 24 plots. Seedbeds burned, plowed, harrowed, dragged, or untreated.
Skull Valley, Utah, 1948	16, 000	1,000 acres scarified before seeding, 500 after seeding. 60 acres scarified and airplane broadcast to nonpelleted seed. ⅓ acre to coated pellets; ⅓ acre to extruded pellets.
Central Arizona, 1961		418 acres divided into 112 experimental plots; seedbeds chained, pitted, and not treated. Pelleted and nonpelleted seed airplane broadcast and drilled.

[1] 1,600 acres flown twice; 800 acres flown 3 times.

TABLE 2.—*Description of large-scale and experimental pellet seedings on western rangelands, 1946–61*—Continued

COATED SEED PELLETS

Location and year seeded	Area seeded to pellets by airplane	Comparative experimental seedings to pellets and seedings to nonpelleted seed
	Acres	
Crane Creek, Idaho, 1949	6, 500	Six 1/40-acre experimental plots—3 hand-broadcast to pellets; 3 to nonpelleted seed.
Summit, Idaho, 1954	1, 270	Nonpelleted seed airplane broadcast on 66 acres; 35 acres plowed and drilled; 1 acre burned and drilled. Two experimental areas (63 plots).[2]
Dubois, Idaho, 1954	660	Nonpelleted seed airplane broadcast on 60 acres; 120 acres plowed and drilled; 360 acres burned and drilled. One experimental area (41 plots).[2]
Sand area, Fort Hall, Idaho, 1954.	650	Nonpelleted seed airplane broadcast on 1,470 acres and drilled on 417 acres. One experimental area (36 plots).[2]
Buckskin Flat, Fort Hall, Idaho, 1954.	1	Nonpelleted seed airplane broadcast on 2,350 acres; 850 acres burned and drilled and 922 acres plowed and broadcast to nonpelleted seed by spreader. Two experimental areas (69 plots).[2]
Ross Fork, Fort Hall, Idaho, 1954.	650	Nonpelleted seed airplane broadcast on 750 acres.
Portneuf River, Fort Hall, Idaho, 1954.	325	Nonpelleted seed airplane broadcast on 1,175 acres of plowed seedbed; 655 acres of unprepared seedbed; and broadcast by spreader on 1,200 acres of plowed seedbed. Two experimental areas (69 plots).[2]

[2] Each area was divided into 3 strips—burned, plowed, and not treated; 11 seeding methods on each strip.

San Carlos Indian Reservation, Arizona

The San Carlos Indian Reservation in Arizona was seeded at two locations—2,500 acres in the Paymaster area and 17,500 acres on the Ash Creek Ranch. Seedings were in the desert-foothill grass type of vegetation at an elevation of 4,500 feet.

Procedures

LARGE-SCALE SEEDING.—Seeding was done between August and October 1946 on unprepared seedbeds. Both areas were sown by airplane to compressed pellets containing seeds of sand dropseed and Lehmann and weeping lovegrasses at a ratio of 33:16:1. Seeding was at the rate of one pellet per square foot with six to eight seeds per pellet.

EXPERIMENTAL FIELD SEEDING.—At Ash Creek, 28 acres were

disked and drilled to pelleted seed of Lehmann and weeping lovegrasses; and 4 acres were drilled to nonpelleted seed of Lehmann lovegrass and crested and western wheatgrasses. These seedings were made at the same season as the large-scale plantings.

Results

LARGE-SCALE SEEDING.—Moisture was favorable in the fall of 1946, but observations in 1947 failed to show any seeded plants on the 20,000 acres (Wagner, 1949; Wagner and Kinkor, 1950). Further observations in 1950, 1954, 1957, and 1961 also failed to show seeded plants.

EXPERIMENTAL FIELD SEEDING.—During October 1946, a few scattered patches of Lehmann lovegrass were found in the drilled area. The stand was extremely poor and spotty (Wagner, 1949).

Hopi Indian Reservation, Arizona

Two seedings were made on the Hopi Indian Reservation north of Winslow, Ariz. Both areas were in the flood plains-grassland type of vegetation in Keams Canyon—one on the Polacca waterspreading area; the other on the Jeddito waterspreading area. Both areas were depleted; the remaining vegetation was mainly western wheatgrass, galleta, blue grama, Indian ricegrass, and various shrubs and weeds. The soil is sandy. Elevation of these flood plains is approximately 5,500 feet.

Procedures

In October and November 1946, 10,000 acres on the Polacca area were seeded to crested and western wheatgrasses. In May and June of 1947, an additional 5,000 acres in the Polacca Valley and 5,000 acres on the Jeddito waterspreading area were seeded to crested wheatgrass and sand dropseed. All seedings were on unprepared seedbeds and were made by airplane with compressed earthen pellets at the rate of one pellet per square foot.

Results

Two years after seeding, a scattering of crested wheatgrass was found in a part of the Polacca area. Most of the plants were within clumps of native galleta. Very few seeded plants had established themselves on the bare soil surface (Wagner, 1949; Wagner and Kinkor 1950). On the Jeddito area in 1954, sand dropseed and western wheatgrass occurred in small amounts. As these are native to the area, it is not known if they can be attributed to the pellet seeding. In 1961 both areas were considered failures.

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Navajo Indian Reservation, Arizona and New Mexico

Seeding on the Navajo Indian Reservation was done on two areas in the Chuska Mountains—one in northwestern New Mexico and the other in northeastern Arizona. Rainfall here is estimated to be between 20 and 28 inches annually. Elevation is approximately 8,000 feet. The seeded areas were timber interspersed with open parks and dotted with small lakes. The timbered areas were either quaking aspen, spruce, and fir; or open stands of ponderosa pine. The soil was relatively deep. All things considered, these areas were favorable seeding sites.

Procedures

Both areas were seeded by airplane with compressed earthen pellets at the rate of one pellet per square foot on an unprepared seedbed. The species used were crested wheatgrass, smooth brome, yellow sweetclover, and timothy. The first area contained 23,708 acres and was seeded between October 25 and December 14, 1947. The second area contained 16,000 acres and was seeded during June and July 1948. In addition, nonpelleted seed was broadcast on deep snow on 810 acres from January 3 to 7, 1948.

Results

Seedlings occurred over both areas, especially where there was soil disturbance and no native vegetation. Because of poor rooting and competition from established plants, seedling mortality was high. By 1961 there was little evidence of seeded plants, and the seedings were classed as failures.[8] Broadcasting nonpelleted seed gave approximately the same seedling stands as broadcasting pelleted seed (Wagner, 1949).

Thorn Creek, Idaho

The Thorn Creek seeding consisted of 20,952 acres on two areas: Rattlesnake Butte and Thorn Creek. Rattlesnake Butte has an elevation of from 4,000 to 4,600 feet and a precipitation of 10 inches. Thorn Creek has an elevation of from 5,000 to 6,000 feet and a precipitation of 13 to 15 inches. Soils in both areas are shallow and rocky and derived from basalt, rhyolite, and loessial deposits.

Both areas once supported a stand of big sagebrush with a good understory of grass. Thorn Creek supported some bitterbrush and chokecherry. Many valuable forage species have disappeared as the result of past use. Fire and past use have reduced Rattlesnake Butte to cheatgrass, some Sandberg bluegrass and sunflower, and other annual weeds.

[8] Unpublished data from the U.S. Bureau of Indian Affairs.

Procedures

Both areas were burned by accidental fires the summer before seeding. They were broadcast by airplane to compressed earthen pellets during the period October 28, 1947, to January 16, 1948. The species used were crested wheatgrass and yellow sweetclover at a ratio of 3:1. Field counts gave 0.4 pellet per square foot with a range from 0 to 1.6. One 1,600-acre area was seeded twice and another 800-acre area three times to check the effect of seeding rates. Many temporary and permanent sample plots were established to check results.

Results

Seedling counts in May 1948 at Thorn Creek showed an average of one plant of crested wheatgrass per 20 square feet and one sweetclover plant per 167 square feet. Only sweetclover was found at Rattlesnake; density was the same as at Thorn Creek (Tisdale and Platt, 1951). By 1950 the sweetclover had disappeared; and the crested wheatgrass at Thorn Creek had increased slightly, mainly as the result of good precipitation during 1948 (Moomaw *et al.*, 1954).

In 1961 there was only one plant of crested wheatgrass per 5,000 square feet at Rattlesnake Butte. On the more favorable Thorn Creek burn there was an average of one plant per 110 square feet on the flats and one plant per 197 square feet on the slopes. Most of these plants were suppressed by native vegetation. This number of plants, after 13 years, is far from a successful seeding (fig. 4).

Figure 4.—*A*, fourteen years after broadcasting compressed pellets by airplane, Rattlesnake Butte is mainly cheatgrass, with an occasional plant of crested wheatgrass. *B*, an adjacent area, which was plowed and drilled to crested wheatgrass, has been grazed for several years and still has a good stand, even in a dry year.

Muskrat Creek, Wyoming

Muskrat Creek is south of Moneta, Wyo. Elevation ranges from 5,800 to 6,800 feet, and precipitation from 8 to 11 inches. The area varies from flats to rough, steep slopes. Soils range from heavy soils on salty flats to clay slopes and bluffs and sandy ridges and dunes. Past grazing has depleted the area. The vegetation is mainly big sagebrush with a sparse understory of needle-and-thread, streambank wheatgrass, blue grama, and Indian ricegrass. There are several areas of shadscale, saltsage, and other shrub species.

Procedures

Compressed earthern pellets containing crested wheatgrass and yellow sweetclover seed were broadcast by airplane on an unprepared seedbed during the winter and spring of 1948. Pellets averaged 1.1 per square foot over the 21,000-acre area. Crested wheatgrass pellets averaged 5.16 seeds per pellet and 1.2 pounds of seed per acre. Yellow sweetclover averaged 5 seeds per pellet and 0.25 pound per acre.

Results

In 1948, a good year, many crested wheatgrass seeds germinated and produced seedlings. However, most of them died during the summer and only scattered plants finally resulted from this seeding. In 1961 on the more favorable sites, there was 0.8 plant of crested wheatgrass per acre with a forage yield of 0.01 pound per acre. The few reseeded plants were competing unsuccessfully with native vegetation. On an adjacent area where brush had been cleared off and the site drilled to crested wheatgrass in the fall of 1948, there was 0.55 plant per square foot and 370 pounds of air-dry grass per acre in 1961 and 511 pounds in 1962.

Golliher Mountain, Nevada

Golliher is a depleted rolling sagebrush-grass area 70 miles northeast of Wells, Nev. Elevation is approximately 5,500 feet.

Procedures

The Golliher area was burned during the summer of 1948. The burn was spotty, and numerous unburned islands of sagebrush remained. Compressed pellets of crested wheatgrass were broadcast by airplane in the fall on 15,000 acres. A small acreage of the burn was drilled to crested wheatgrass.

Results

Examination during 1949 showed only a few seedlings of crested wheatgrass from the pellet seeding on the large broadcast area. In

1961 there were no plants from the pellet seeding whereas the drilled area had an excellent stand of crested wheatgrass.

Manti-LaSal National Forest, Utah

Seeding on the Manti-LaSal National Forest in southeastern Utah was in four types of vegetation (Bleak and Phillips, 1950). These types ascended in elevation from the juniper-pinyon type at about 6,500 feet through the mountain brush and ponderosa pine to the aspen type at the upper limits at about 8,400 feet. Annual precipitation varies from about 15 inches in the juniper-pinyon woodland to 28 inches in the aspen. Soils are mainly sandy loam.

The juniper-pinyon woodland has a spare brush and herbaceous understory. The mountain brush consists mainly of dense stands of big sagebrush and frequent thickets of serviceberry and gambel oak. The ponderosa pine type is an open stand of timber with a sparse brush and herbaceous understory. The aspen type consists of dense stands of quaking aspen with brushy and weedy openings. Seedings by conventional methods have given good stands and show that all types are favorable for seeding.

Procedures

LARGE-SCALE SEEDING.—Compressed earthen pellets were broadcast by airplane in September 1948, on 6,443 acres of unprepared seedbed and nonpelleted seed on 1,284 acres. Species used were bulbous bluegrass, yellow sweetclover, crested wheatgrass, smooth brome, tall oatgrass, orchardgrass, and timothy. The different species were used according to their adaptability for each of the four types of vegetation. Seeding rates for pellets were either one or two pellets per square foot (1.2 or 2.4 pounds of seed per acre). Nonpelleted seed was broadcast at 10 pounds per acre.

The total seeding cost was $2.40 per acre for one pellet per square foot, $4.80 per acre for two pellets, and $3.57 per acre for nonpelleted seed.

EXPERIMENTAL FIELD SEEDING.—Seventy-three acres in three of the vegetation types—pinyon-juniper, mountain brush, and ponderosa pine—were divided into 48 plots to which 24 treatments were applied. These treatments included hand and airplane broadcast sowing on seedbeds prepared by (1) plowing, (2) pipe harrowing, (3) dragging, (4) burning, and (5) no treatment. Seeding was done at the same time and at the same seeding rates as on the large acreage.

Results

LARGE-SCALE SEEDING.—Plant counts and yields in 1955 showed that stands from airplane broadcast pellets yielded from 0.1 pound

of grass per acre in the mountain brush to 134 pounds in the aspen. Stands from nonpelleted seed yielded from 9 pounds per acre in the juniper-pinyon to 251 pounds in the aspen. The better stands in the aspen were attributed to leaf fall covering the seed. Nonpelleted seed produced from 15 to 165 times as many seedlings as did pelleted seed.

EXPERIMENTAL FIELD SEEDING.—In 1955, sample yields from the experimental broadcast seeding in the mountain-brush type of vegetation were as follows:

	Yield (pounds per acre)		
Seeding method	*No tillage*	*Plowed*	*Burned*
2 pellets per square foot	1	136	182
Nonpelleted seed	77	652	710

It was concluded that yields of herbage on the mountain brush plots increased in proportion to the amount that tillage reduced competition with native plants and provided seed covering. Also, seed in compressed pellets did not have any advantage over nonpelleted seed in improving grass stands in any of the four range types (Bleak and Hull, 1958).

Skull Valley, Utah

Skull Valley, a broad, gently sloping valley 40 miles southwest of Grantsville, Utah, is dominated mostly by shadscale with some patches of sagebrush and greasewood. Cheatgrass is the major understory vegetation. Elevation is 4,600 feet, and precipitation is approximately 8 inches annually. Soils are deep, light gray, and a fine to medium texture.

Procedures

LARGE-SCALE SEEDING.—Compressed earthen pellets were broadcast by airplane on 16,000 acres in October and November 1948, mostly on an unprepared seedbed. However, 1,000 acres were scarified before broadcasting and 500 acres after broadcasting to kill existing vegetation. Crested wheatgrass and yellow sweetclover were used at a ratio of 3:1. There was an average of 0.72 pellet per square foot with 6.1 seeds per pellet. This amounted to 1¼ pounds of seed per acre.

EXPERIMENTAL FIELD SEEDING.—Sixty acres, half of which were scarified before seeding, were broadcast to nonpelleted seed. A ⅓-acre plot was seeded to extruded pellets and another ⅓-acre plot to coated pellets.

Results

LARGE-SCALE SEEDING.—On May 11, 1949, no seeded plants were found on the seeded area. On June 14, a few small plants were found. The growth of native plants was phenomenal, the result of good winter and spring moisture. The Weather Bureau reported for that area, "The seasonal precipitation is about 50 percent above normal and the outlook for water storage supply and soil moisture is excellent." In August 1952, May 1954, and August 1961 there were a few scattered seedlings of crested wheatgrass.

EXPERIMENTAL FIELD SEEDING.—The best seedling establishment and survival was with nonpelleted seed on the scarified seedbed, followed by pelleted seed on the scarified seedbed. In August 1961, only a few plants were found and the seeding was classed as a failure. No plants were found on the two small areas seeded to other types of pellets.

Central Arizona

Experimental field seedings in Central Arizona were made to test different methods of seeding compressed earthen pellets and nonpelleted seed on seedbeds prepared by different methods. The primary area is near Congress Junction, about 25 miles northwest of Wickenburg. Elevation is about 3,000 feet and annual precipitation is about 10 inches. The soil is a light sandy loam. Vegetation is mainly cholla, snakeweed, mesquite, and joshua tree. There are occasional plants of grass such as tobosa, black grama, and three-awn.

The secondary area is near Cordes, about 40 miles southeast of Prescott. Elevation is about 3,750 feet and annual precipitation is about 14 inches. The soil is a loam overlain with an erosion pavement. Vegetation is mainly snakeweed with many annual weeds and grasses and some grass plants such as curly mesquite and side-oats grama.

Procedures

At the primary area there were 96 experimental plots, each 3.67 acres. Seedbed preparation was pitting, chaining, and no treatment. Nonpelleted seed and pellets were broadcast by airplane and drilled. At the secondary area there were 16 plots, each 4.13 acres; they were broadcast to pellets and nonpelleted seed on an unprepared seedbed. At both areas each treatment plot was divided into three subplots, which were seeded to three individual species: Lehmann and Boer lovegrasses and black grama. Seedings were made in late June and early July 1961. Rodents and ants were controlled.

Results

Results are not yet available on this study, which will be carried out for at least another year.[9]

SEEDINGS WITH COATED SEED PELLETS

Large-scale and experimental field seedings of coated seed pellets were made at Crane Creek, Idaho, in 1949. In 1954, large-scale studies were conducted in southern Idaho at Summit, Dubois, and Fort Hall (Sand area, Buckskin Flat, Ross Fork, and Portneuf River). Also, several experimental field seedings were made at Summit, Dubois, Sand area, Buckskin Flat, and Portneuf River. Because the experimental seedings are very similar, they are discussed together.

Crane Creek, Idaho

The Crane Creek area near Weiser, Idaho, consists of a large flat and an adjoining slope totaling 6,500 acres. Elevation ranges from 3,500 to 4,500 feet and annual precipitation from 13 to 15 inches. On the slope, the vegetation is big sagebrush and bunch grasses; on the flat, it is mainly cheatgrass. The soils on the slope are light-textured and moderately deep, whereas on the flat they are heavier and slightly deeper.

Two sites for experimental field seedings were selected at Crane Creek; the third was near Pocatello, Idaho. The Pocatello site is sagebrush-grass with a good deep soil. The elevation at Pocatello is approximately 4,500 feet and annual precipitation is 13 inches.

Procedures

LARGE-SCALE SEEDING.—The 6,500-acre tract at Crane Creek was burned in the fall of 1948 to prepare it for seeding. Seeding was by airplane in late March 1949. Coated pellets of crested wheatgrass were broadcast at the rate of 32 pounds of pellets or 4 pounds of seed per acre.

EXPERIMENTAL FIELD SEEDING.—On each of the three experimental areas, a $\frac{1}{40}$-acre plot was hand-broadcast to coated pellets of crested wheatgrass at the rate of 6 pounds of seed per acre. A similar plot was broadcast to 6 pounds of nonpelleted seed per acre. Seedings were made in the fall of 1949 on burned seedbeds.

Results

LARGE-SCALE SEEDING.—The summer of 1949 was extremely dry at Crane Creek. Only one seedling of crested wheatgrass was found

[9] Unpublished data from the University of Arizona.

per 250 square feet. In 1950 and 1951 no trace of seedlings remained (Moomaw *et al.*, 1954).

EXPERIMENTAL FIELD SEEDING.—In July 1950, the number of seedlings per square foot on the experimental plots were as follows:

Site	Seedlings per square foot	
	Pelleted seed (number)	Nonpelleted seed (number)
Crane Creek No. 1	0. 15	0. 32
Crane Creek No. 2	. 36	. 61
Pocatello	. 93	. 76

Observations in 1951 showed seedling mortalities of 25 and 70 percent at the two Crane Creek sites. Mortality was approximately the same for both the pelleted and the nonpelleted seed. The seedling loss was attributed to poor rooting.

In connection with this study, several other small-scale field seeding trials were made with both coated and compressed pellets and with nonpelleted seed. None of the seedings showed any advantage for pellets (Moomaw, 1951; Moomaw *et al.*, 1954).

Summit, Idaho

Summit is a rolling area north of Shoshone, Idaho. There are many rhyolitic and basaltic outcrops. Elevation is 5,000 feet and annual precipitation is 14 inches. The soil is a loam. Principal species are big sagebrush and low sagebrush with a sparse understory of beardless bluebunch wheatgrass and other grasses. Sagebrush averaged about 43 plants per 100 square feet.

Procedures

This area was burned clean on August 12, 1954. Coated pellets of crested wheatgrass were broadcast by airplane on November 3, 1954. Pelleted seed was used on 1,270 acres and nonpelleted seed on 66 acres. Thirty-five acres were plowed and drilled, and one acre was burned and drilled. All seedings were at the rate of 6 pounds of seed per acre.

Results

During 1955, 1956, and 1961, counts showed the following number of plants per square foot:

Seeding method	Plants per square foot		
	1955	1956	1961
Burned and airplane broadcast to pellets	0. 1	0. 03	0. 02
Burned and drilled to nonpelleted seed	4. 5	2. 3	1. 3
Plowed and drilled to nonpelleted seed	5. 2	2. 4	1. 4

Dubois, Idaho

The Dubois seeding is on a gentle south-facing slope north of Dubois, Idaho. Elevation is 6,000 feet and annual precipitation is 15 inches. The soil is a loam with gravel and rocks throughout the profile. Big sagebrush and three-tip sagebrush are dominant. Sagebrush averaged about 44 plants per 100 square feet. The understory grasses were mainly streambank wheatgrass and bluebunch wheatgrass. Dry farming and conventional range seedings with crested and intermediate wheatgrasses near this site have been successful.

Procedures

The area was burned on September 16, 1954. On November 9, coated seed pellets of crested wheatgrass were broadcast by airplane on 660 acres and nonpelleted seed on 60 acres. An adjacent 360-acre area was burned and drilled, and another 120-acre area was plowed and drilled. All seedings were at the rate of 6 pounds of seed per acre (fig. 5).

Figure 5.—Drilling seed was superior to broadcasting coated seed pellets by airplane in the 1954 seedings at Dubois. En route from the area that was burned and drilled, one drill strip was made through the area that was burned and airplane broadcast to coated pellets. A good stand of crested wheatgrass is plainly visible on the drill strip. There is practically no crested wheatgrass in the pellet-seeded area on both sides; the sagebrush has reinvaded and some native grasses are thickening up to make a sparse understory.

Results

Counts were made on two areas in 1955 and 1961. Numbers of seedlings per square foot on a burned seedbed were as follows:

Seeding method	*Seedlings per square foot*	
	1955	*1961*
Airplane broadcast to pellets	0. 1	0. 02
Drilled to nonpelleted seed	7. 9	2. 3

Sand Area, Fort Hall, Idaho

The Sand area is a large flat on the Fort Hall Indian Reservation at an elevation of 4,450 feet. Annual precipitation is about 10 inches. The soil is a loamy sand with considerable gravel. Vegetation was formerly big sagebrush and perennial grass. Because of fires and past use, the area now supports mainly cheatgrass but has a fair stand of sand dropseed and some big sagebrush.

Procedure

The 2,537-acre seeding site was burned during the summer of 1954. On November 16, coated pellets of crested wheatgrass were broadcast by airplane at rates of 1, 2½, or 6 pounds of seed per acre on 650 acres. Nonpelleted seed was broadcast by airplane on 1,470 acres and drilled on 417 acres, both at 6 pounds per acre.

Results

Some seedlings established themselves during the first season, especially on the drilled area. However, the fire did not kill the cheatgrass and it was such severe competition that few seeded plants survived the first summer. Plant counts during 1961 were as follows:

Seeding method (6 pounds per acre)	*Plants per square foot*
Burned and drilled	0. 010
Burned and broadcast nonpelleted seed	. 003
Burned and broadcast pellets	. 003

This seeding showed the need for covering seed and killing competing cheatgrass to obtain successful seeded stands.

Buckskin Flat, Fort Hall, Idaho

Buckskin Flat is a large, nearly level site 7 miles northeast of Fort Hall. Elevation is 4,700 feet. Annual precipitation is approximately 11 inches. The soil is a sandy loam. Vegetation was formerly sagebrush and perennial grass but is now cheatgrass with scattered patches of big sagebrush, Douglas rabbitbrush, and some perennial

grasses. There have been several successful range seedings with crested wheatgrass in this area.

Procedures

All seedings were at the rate of 6 pounds of crested wheatgrass per acre in November 1954. Nonpelleted seed was broadcast by airplane on 2,350 acres and coated pellets on 1 acre on a clean burn. An additional 850 acres were burned and drilled to nonpelleted seed, and 922 acres were plowed and nonpelleted seed was broadcast by spreader

Results

In 1961, the area that was seeded by airplane was almost a complete failure with only 0.003 plant per square foot. Where the seed was drilled, there were 2.7 plants per square foot or 900 times more than from broadcasting on the same seedbed.

Ross Fork, Fort Hall, Idaho

The Ross Fork area is 10 miles east of Fort Hall on north and east slopes. Elevation ranges from 5,500 to 7,000 feet. Annual precipitation is about 16 inches. Soil is mainly dark-colored silt loam. Vegetation is sagebrush and grass with many mountain brush species and pockets of quaking aspen. There have been many successful range seedings in this area and dry farming is successful.

Procedures

In September 1954, an accidental fire burned the area clean. In many places, ashes were several inches deep. Crested wheatgrass was broadcast by airplane on November 21, 1954. Coated seed pellets were used at 1, 2½, or 6 pounds of seed per acre on 650 acres and nonpelleted seed at 6 pounds per acre on 750 acres.

Results

Counts in 1961 showed that where ashes were 2 inches deep or more, there was a good stand of seeded grass. With less ashes, there were only poor to fair stands. Where ashes were shallow or lacking, the seeding was classed as a failure. At the same seeding rate, there was no difference in stands resulting from pelleted or nonpelleted seed.

Portneuf River, Fort Hall, Idaho

The Portneuf area is a south sloping basin on the headwaters of the Portneuf River about 25 miles east of Fort Hall. Elevation ranges from 5,300 to 6,000 feet. Precipitation is about 16 inches annually. Soils are light-colored silt loam. Three-tip sagebrush is dominant,

but there are several other brush species. Major understory species are streambank wheatgrass, Sandberg bluegrass, Nevada bluegrass, and needle-and-thread. In this area, dry farming is successful and good stands of crested wheatgrass have resulted from past range seedings.

Procedures

During the fall of 1954 Portneuf had many and varied treatments on 3,355 acres as follows: 325 acres were plowed and coated seed pellets of intermediate wheatgrass were airplane broadcast at 1, 2½, or 6 pounds of seed per acre; 1,175 acres were plowed and nonpelleted seed of intermediate wheatgrass was airplane broadcast on 525 acres and crested wheatgrass on 650 acres. Both species were sown at a rate of 6 pounds per acre. Intermediate wheatgrass seed was airplane broadcast at 6 pounds per acre on 655 acres with no seedbed preparation. Crested wheatgrass was broadcast by spreader on a plowed seedbed at 7 pounds per acre on 1,200 acres.

Results

All treatments on this seeding failed. Within these large seedings the experimental plots that were plowed and drilled produced good stands.

Experimental Seedings

Eight experimental seedings of coated seed pellets were made within five large-scale seedings, as follows: Summit, two areas; Dubois; Sand area; Buckskin, two areas; and Portneuf, two areas. Site descriptions were given under the large-scale seedings.

Procedures

Each 4-acre experimental area was divided into three strips: one was plowed, one burned, and one not treated. The plots were seeded at right angles to the 3 strips by an average of 11 seeding methods. Seeding methods included airplane and hand broadcasting of seed and two types of coated seed pellets at different rates and drilling at different rates. In general, crested wheatgrass was used on all except the two Portneuf areas, where intermediate wheatgrass was used. Plowing, drilling, and broadcasting were done in November 1954 (figs. 6 and 7).

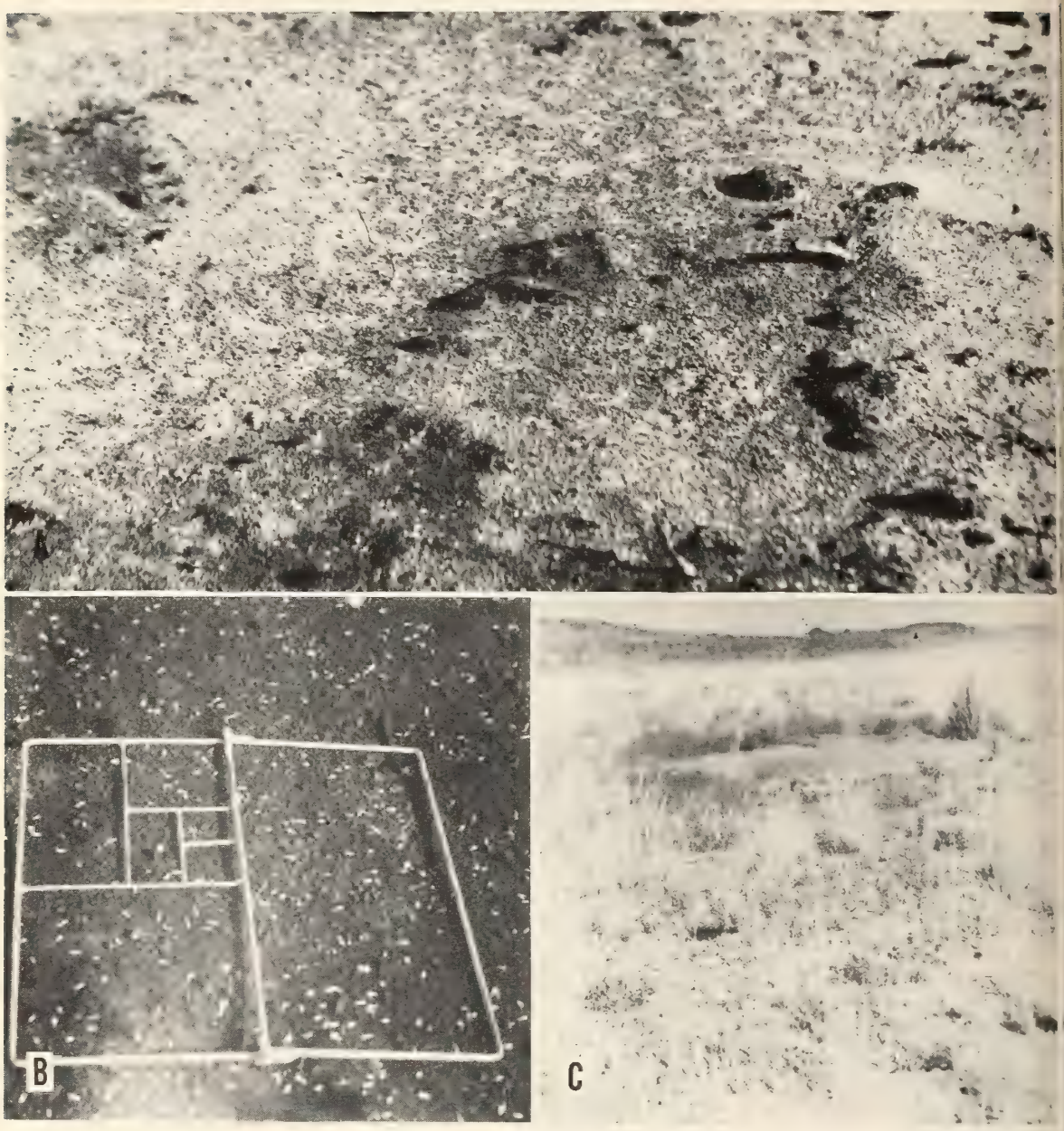

Figure 6.—*A* and *B*, Coated seed pellets broadcast at 6 pounds per acre by airplane on a sagebrush burn at Summit, Idaho, in November 1954 were not covered by sagebrush ashes. *C*, In 1956 the seeded plants on this area produced only 2 pounds of air-dry herbage per acre. Native grasses, weeds, and shrubs are increasing. Compare this stand with the adjacent drilled area in figure 7.

Figure 7.—*A*, Untreated seed drilled at 6 pounds per acre on a burned seedbed at Summit, Idaho. *B*, In 1956 the area produced 453 pounds of air-dry herbage per acre. Compare this stand with the adjacent pellet seeding in figure 6.

Results

Plants were counted on all areas. The numbers surviving to the second year are shown in table 3 (Hull, 1959). In 1961, air-dry crested wheatgrass per acre on plots seeded at 6 pounds of seed per acre was as follows:

Location	*Air-dry crested wheatgrass per acre*	
	Plots plowed and drilled to non-pelleted seed (pounds)	*Plots burned and airplane broadcast to pellets (pounds)*
Dubois	1, 128	2
Sand	1, 165	23
Buckskin No. 1	1, 425	1
Buckskin No. 2	1, 465	27
Portneuf No. 2	1, 303	4

TABLE 3.—*Average number of plants per square foot in 1956 from seeding 6 pounds of grass seed per acre by different methods of seeding on plowed and burned seedbeds at 8 locations in southern Idaho in November 1954*

Species and seeding method	Plants per square foot on—			
	Plowed seedbed		Burned seedbed	
	Nonpelleted seed	Pelleted seed	Nonpelleted seed	Pelleted seed
	Number	*Number*	*Number*	*Number*
Crested wheatgrass:				
Drilled	1.4	(1)	0.6	(1)
Hand broadcast	.5	0.4	.1	0
Airplane broadcast	.3	.4	0	0
Intermediate wheatgrass:				
Drilled	2.0	(1)	.1	(1)
Hand broadcast	.4	.5	0	0
Airplane broadcast	.4	.4	0	0

[1] No treatment.

The counts of 2-year-old plants and the yields from 7-year-old plants show plainly the advantage of plowing and drilling in producing a good stand of seeded grass.

COSTS

Major items of cost in aerial pellet seeding are (1) seed, (2) pelleting material, (3) pellet manufacture, (4) seeding by airplane, and (5) supervision. Per acre costs of seeding large areas with pelleted seed, and results of the seeding, are shown in table 4.

TABLE 4.—*Costs and results on 16 large-scale pellet seedings* [1]

COMPRESSED EARTHEN PELLETS

Location and seeding date	Cost per acre	Moisture at time of seeding	Results
Papago Indian Reservation, Arizona, 1946.	$2.32	Favorable	Failure.
San Carlos Indian Reservation, Arizona, 1946.	2.00	do	Do.
Hopi Indian Reservation, Arizona, 1946–47.	2.10	do	Do.
Navajo Indian Reservation, Arizona and New Mexico, 1947–48.	2.42	do	Do.
Thorn Creek, Idaho, 1947–48	2.56	Normal	Unsatisfactory.
Muskrat Creek, Wyoming, 1947–48	2.33	do	Failure.
Golliher Mountain, Nevada, 1948	3.25	Favorable	Do.
Manti-LaSal National Forest, Utah, 1948.	2.42	do	Unsatisfactory.
Skull Valley, Utah, 1948	3.52	Above normal	Failure.

See footnote at end of table.

TABLE 4.—*Costs and results on 16 large-scale pellet seedings* [1]—Continued

COATED SEED PELLETS

Location and seeding date	Cost per acre	Moisture at time of seeding	Results
Crane Creek, Idaho, 1949	4. 31	Not favorable	Failure.
Summit, Idaho, 1954	8. 78	Favorable	Unsatisfactory.
Dubois, Idaho, 1954	8. 78	do	Do.
Sand area, Fort Hall, Idaho, 1954	7. 35	do	Failure.
Buckskin Flat, Fort Hall, Idaho, 1954.	7. 35	do	Unsatisfactory.
Ross Fork, Fort Hall, Idaho, 1954	7. 35	do	Do.
Portneuf River, Fort Hall, Idaho, 1954.	9. 93	Not favorable	Failure.

[1] For compressed earthen pellets, costs are based on 1 pellet per square foot For crested wheatgrass this averages 1.2 pounds of seed and 72 pounds of pellets per acre. For coated seed pellets, costs are based on 6 pounds of seed per acre.

Conventional seeding methods are about equal in cost to seeding coated seed pellets by airplane.

The lower costs for seeding compressed earthen pellets are the result of lower seeding rates. Advocates of compressed earthen pellets claim that seeding rates can be reduced to 2 or 1 pound per acre or even less. The reasoning behind this claim is not clear. One reason given is that the resulting stand of grass will be so thin that livestock will not find it worth grazing. This is hardly a suitable objective of range seeding. Furthermore, competing vegetation and the lack of seed covering make it difficult and slow for plants in a thin stand to spread and provide a good, grazable stand of grass.

Six pounds of crested wheatgrass seed per acre is recommended for range seedings with good seedbed preparation and seeding methods (U.S. Dept. Agr., 1948). Observations show that a compressed or coated seed pellet has no better chance of becoming an established plant on arid rangelands than has nonpelleted seed. Thus it would seem that the seeding rates advocated for pelleted seed, which are considerably lower than rates recommended for range seedings with nonpelleted seed, are not justified.

Total costs and returns from seeding coated pellets are shown in table 5. Per dollar expended crested wheatgrass seed drilled on a plowed seedbed produced three times as much grass as seed or pellets which were airplane broadcast on a plowed seedbed. For every dollar invested, plowing and drilling returned 71 pounds of grass compared to 1 pound of grass for airplane pellet seeding on a burned seedbed.

With compressed pellets a commonly accepted cost for manufacture of pellets is $1.25 per acre when using the recommended one pellet per square foot. On the Manti-LaSal project in Utah it cost $1.40

to pellet 1.2 pounds of seed per acre, 30 cents for seed, 55 cents for flying, and 15 cents for other costs, for a total of $2.40 per acre. Ten pounds of seed broadcast by airplane on this project cost $3.47 per acre, but gave much better stands than did two pellets per square foot at $4.80 per acre (Bleak and Phillips, 1950; Bleak and Hull, 1958).

Besides the cost of pelleting there is the additional weight of the pelleting materials. With a seed-earthen pellet ratio of 1:60, such as for crested wheatgrass, this is 60 times more weight to haul and distribute. On coated seeds the ratio is 1:5, still an expensive item.

TABLE 5.—*Seeding costs and returns from a 2-year-old stand of crested wheatgrass from seeding by various methods (6 pounds of seed or seed equivalent per acre)*

Seeding method	Cost per acre	Air-dry grass per acre	Grass per year per dollar invested
	Dollars	*Pounds*	*Pounds*
Plowed seedbed:			
Drilled seed	6. 90	487	71
Airplane broadcast seed	6. 00	125	21
Airplane broadcast pellets	11. 40	146	13
Burned seedbed:			
Drilled seed	3. 65	154	42
Airplane broadcast seed	2. 75	17	6
Airplane broadcast pellets	8. 15	11	1

Source: Table 7, Hull (1959).

SUMMARY AND CONCLUSIONS

This publication brings together all the available documented information on pellet seeding of western rangelands including (1) 16 large-scale range seedings totaling more than 180,000 acres, (2) widespread experimental field tests, and (3) numerous laboratory and greenhouse studies. Compressed earthen pellets and coated seed pellets were used in the seedings, which covered a wide range of conditions during the 16-year period 1946–61. Extruded seed pellets were used in one test in 1951.

Large-scale airplane seedings with compressed earthen pellets and with coated pellets were made during five seasons. Of the 16 seedings reported, 10 were declared failures and the remaining 6 unsatisfactory. Most of the seedings were re-examined during one or more years after they were initially classified as failures or unsatisfactory, and 14 of the 16 were examined again in 1961. The seedings did not improve with additional time.

Most of the large-scale field plantings were paralleled by experimental studies in which airplane broadcasting of pelleted seed was subjected to direct comparison with other methods of range revegetation. These studies showed that pelleted seed had no advantage over nonpelleted seed so far as grass establishment is concerned. The studies also confirmed a great mass of data indicating that drilling is superior to broadcasting, and that successful establishment of grass on arid rangelands under conditions encountered in this study requires elimination of competing vegetation.

Greenhouse and laboratory studies revealed that a varying but sometimes very high percentage of the seeds of grasses put into compressed earthen pellets were injured by the pelleting process. Coated seed pellets retained high germinability.

Airplane broadcasting of compressed earthen pellets on an unprepared seedbed at a rate on only 1.2 pounds of seed per acre (the rate recommended by the manufacturer) cost $2.55 per acre. No satisfactory stands were obtained. In some studies, two or three times the recommended rate of seeding was used, at additional cost. No acceptable stands were obtained.

On seedbeds prepared by burning, airplane broadcasting of 6 pounds of seed in coated seed pellets yielded in the second year 1½ pounds of grass per dollar invested. Broadcasting of natural seed yielded 6 pounds, and drilling yielded 42 pounds.

When the seedbed was prepared by plowing, airplane broadcasting of coated seed pellets yielded 13 pounds of grass per dollar invested. Broadcasting of natural seed yielded 21 pounds, and drilling yielded 71 pounds.

Pelleted seed cannot be recommended for revegetating western rangelands. This conclusion is reached after critical evaluation of every available documented study with pellets, including re-examination of most of the seeded sites.

In all the studies conducted to date, there is no known account on western rangelands of a single successful stand produced by airplane broadcasting of either compressed earthen or coated seed pellets.

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LIST OF PLANTS

Common name	*Scientific name*
Aspen, quaking	*Populus tremuloides* Michx.
Beet, sugar	*Beta vulgaris* L.
Bitterbrush	*Purshia tridentata* (Pursh) DC.
Bluegrass, bulbous	*Poa bulbosa* L.
Bluegrass, Nevada	*P. nevadensis* Vasey ex Scribn.
Bluegrass, Sandberg	*P. secunda* Presl
Brome, smooth	*Bromus inermis* Leyss.
Cheatgrass	*B. tectorum* L.
Chokecherry	*Prunus virginiana* var. *demissa* (Nutt.) Sarg.
Cholla	*Opuntia* spp.
Dropseed, sand	*Sporobolus cryptandrus* (Torr.) Gray
Fir	*Abies* sp.
Galleta	*Hilaria jamesii* (Torr.) Benth.
Grama, blue	*Bouteloua gracilis* (HBK.) Lag. ex Steud.
Grama, sideoats	*B. curtipendula* (Michx.) Torr.
Greasewood	*Sarcobatus vermiculatus* (Hook.) Torr.

Common name	*Scientific name*
Joshua tree	*Yucca brevifolia* Engelm.
Juniper, Utah	*Juniperus osteosperma* (Torr.) Little
Lovegrass, Lehmann	*Eragrostis lehmanniana* Nees
Lovegrass, weeping	*E. curvula* (Schrad.) Nees
Mesquite	*Prosopis juliflora* (Sw.) DC.
Mesquite, curly	*Hilaria belangeri* (Steud.) Nash
Needle-and-thread	*Stipa comata* Trin. & Rupr.
Oak, Gambel	*Quercus gambellii* Nutt.
Oatgrass, tall	*Arrhenatherum elatius* (L.) Presl
Orchardgrass	*Dactylis glomerata* L.
Pine, pinyon	*Pinus edulis* Engelm.
Pine, ponderosa	*P. ponderosa* Dougl. ex P. & C. Laws.
Rabbitbrush, Douglas	*Chrysothamnus viscidiflorus* (Hook.) Nutt.
Ricegrass, Indian	*Oryzopsis hymenoides* (R. & S.) Ricker
Sagebrush, big	*Artemisia tridentata* Nutt.
Sagebrush, low	*A. tridentata* subsp. *arbuscula* (Nutt.) H. & C.
Sagebrush, three-tip	*A. tripartita* Rydb.
Saltsage	*Atriplex nuttallii* subsp. *gardneri* (Moq.) H. & C.
Serviceberry	*Amelanchier alnifolia* Nutt.
Shadscale	*Atriplex confertifolia* (Torr. & Frem.) S. Wats.
Snakeweed	*Gutierrezia* spp.
Spruce	*Picea* sp.
Sweetclover, yellow	*Melilotus officinalis* (L.) Lam.
Sunflower	*Helianthus annus* L.
Three-awn	*Aristida* spp.
Timothy	*Phleum pratense* L.
Tobosa	*Hilaria mutica* (Buckl.) Benth.
Wheatgrass, beardless bluebunch	*Agropyron inerme* (Scribn. & Smith) Rydb.
Wheatgrass, bluebunch	*A. spicatum* (Pursh) Scribn. & Smith
Wheatgrass, crested	*A. desertorum* (Fisch. ex Link) Schult.
Wheatgrass, fairway	*A. cristatum* (L.) Gaertn.
Wheatgrass, intermediate	*A. intermedium* (Host) Beauv.
Wheatgrass, streambank	*A. riparium* Scribn. & Smith
Wheatgrass, western	*A. smithii* Rydb.

U.S. GOVERNMENT PRINTING OFFICE: 1963 O—669605